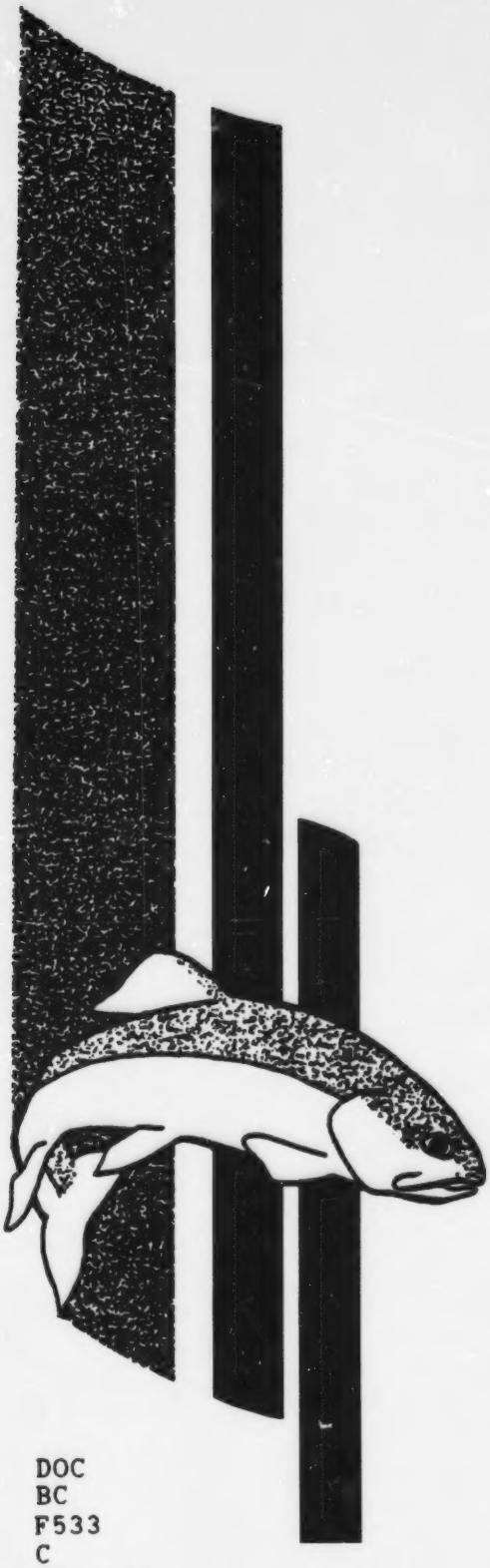

Salmonid escapement enumeration on the Keogh River: a demonstration of a resistivity counter in British Columbia

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Province of British Columbia

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Salmonid escapement enumeration on the Keogh River: a demonstration of a resistivity counter in British Columbia

By

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ABSTRACT

McCubbing, D.J.F, B.Ward and L.Burroughs, 1999. Salmonid escapement enumeration on the Keogh River: a demonstration of a resistivity counter in British Columbia.

A Logie 2100C resistivity fish counter was installed in the Keogh River in the summer of 1997. Data were collected on fish numbers, sizes and time of migration and compared to alternative methods of enumeration (area-under-the-curve and mark-recapture estimates). Counter escapement estimates of 8246 coho adults, 8505 pink salmon and 92 steelhead adults were calculated based on observed counter efficiency, through video validation techniques. Area-under-the-curve (AUC) estimates for pink salmon were higher (15,631 adults) in part due to some escapement into the river occurring before counter operation began. Coho, AUC estimates varied and very dependant on the values used for residence time in the stream count areas. AUC estimates ranged from 5411 to 13,060 adults, with no confidence limits available due to low tag re-sightings. Mark-recapture data for steelhead predicted a similar value for escapement to counter data, with an estimate of 98 fish.

Counter efficiency was observed to be above 80% (mean 93%) in all environmental and migration periods, except during saltwater intrusion events caused by high spring tides. Counter efficiency was negatively related to the number of fish enumerated per unit time, with multiple fish events responsible for much of the counting error.

ACKNOWLEDGEMENTS

We thank the Department of Fisheries and Oceans, Habitat Restoration Branch for financial support through HRSEP which provided funds to continue the development of an automated counter. Gary Logan and Angela Sinclair assisted in this respect. Greame Bull, manager of the Quatse River hatchery (NVISEA) who administered the project, assisted with office space, workshop tools and space, whilst also providing some volunteer time when required. Kent Simpson offered useful observations on experimental design and data interpretation, whilst Jim Irvine and Richard Bailey assisted with area-under-the-curve procedures. The UFAWV/Native brotherhood of Alert Bay, provided manpower assistance of three displaced fishers who undertook much of the field sampling.

INTRODUCTION

This report documents the effective use of a resistivity counter in a medium sized coastal stream in British Columbia. The primary objective of the project was to count upstream migrating adult salmonids, pink and coho salmon and steelhead trout, to provide escapement estimates with acceptable count efficiencies, meanwhile comparing this methods against more often used area-under-the-curve assessment and mark-recapture estimate methods, in both economic and data confidence terms. The need for improved estimates of salmonid escapement for future management of stocks is a key recommendation of the Pacific Fisheries Conservation Councils first report on salmon management (Anon 1999).

We assessed the effectiveness of the Logie 2100C (Aquantic Ltd, Rosshire, Scotland) resistivity fish counter at counting and sizing salmonids over a wide range of flows and escapement abundance. This work will build on population dynamics data gathered from over 20 years of salmonid juvenile abundance in-stream, smolt enumeration, and adult steelhead run size estimates (Fig. 1; Irvine and Ward 1989; Ward and Slaney 1993; McCubbing and Ward 1998, Ward 1999). Coho escapement estimates are used along with smolt yield estimates, as for steelhead (Ward 1999), to assess marine survival and exploitation rates, enabling the partitioning of the freshwater and marine components of salmonid recruitment. These data are necessary to provide informed stock management advice.

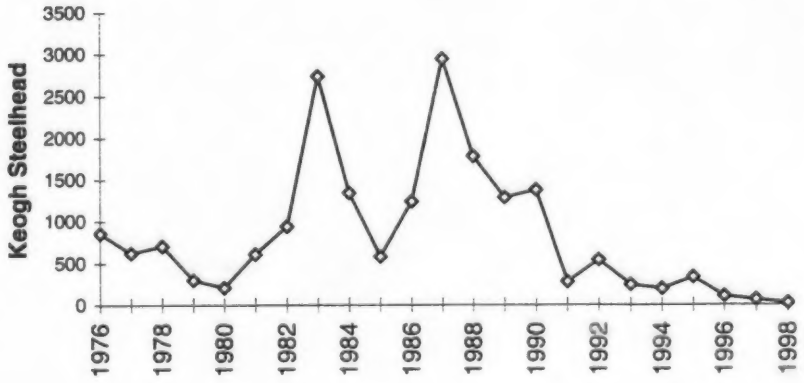

Figure 1. Natural variability in wild steelhead populations over time in the Keogh River, North Vancouver Island, from Ward and McCubbing 1998 (pre 1998 estimates based on mark-recapture data).

STUDY AREA AND METHODS

Study Area

The Keogh River is a third-order coastal stream situated near northern end of Vancouver Island. The river flows Northeast for 33km from Keogh Lake and drains into Queen Charlotte Strait south of Port Hardy, B.C (127.4° W, 50.6° N, Fig 2). Minimum and maximum annual discharges are $0.1 m^3 \cdot s^{-1}$ to $254 m^3 \cdot s^{-1}$ with a mean of ca. $5.3 m^3 \cdot s^{-1}$. A more detailed description of the watershed was provided in Ward and Slaney (1979, 1988, 1993a,b) and previous research on steelhead population dynamics were summarised in Ward (1999).

Counter Site

The counter channels were built into an existing sill at the counting weir which is at the tidal limit (Mottram 1977). Four channels were constructed, three of approximately 2.0 m width and one of 4.0 m width (Fig. 2). The channels consisted of three electrodes (12 x 12 mm square bar stainless steel) installed in a high density polyethylene plastic (HDPE) pad on the downstream slope of a "Crump weir" face (downstream slopes range from 1:6 to 1:8, upstream slopes are 1:2, Crump 1952). The distance between electrodes pairs was 350mm. Electrodes were insulated from the side wall of the channel by a 6 mm thick sheet of plastic, to a height of 40cm. All connections from the electrodes to the fish counter were made with insulated materials to avoid the potential for short circuits (Gray 1997).

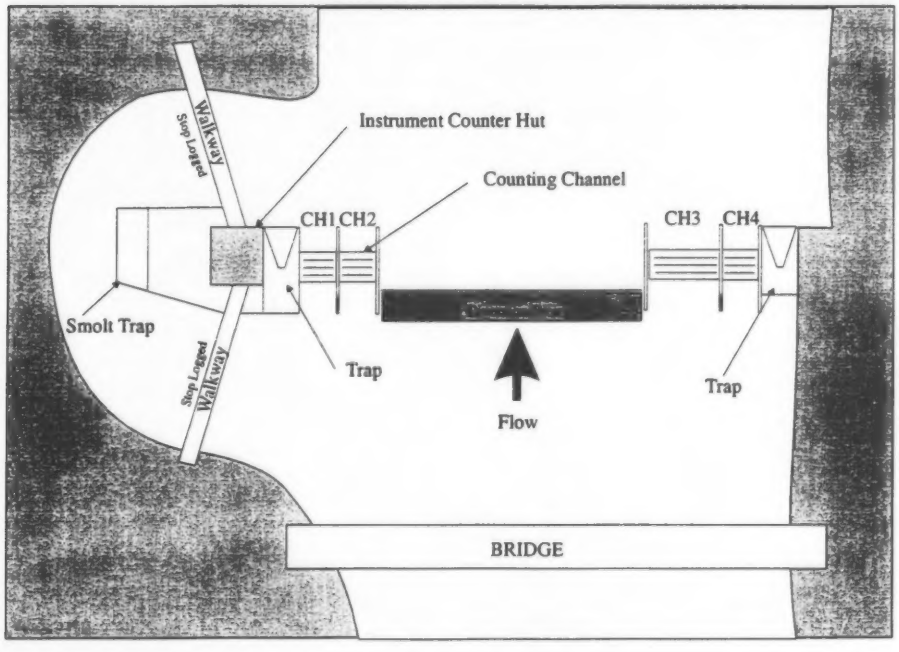

Figure 2. Design of fish counting station, Keogh River 1998.

Experimental Design

Counter operation was tested using three species of salmonids and three escapement estimates. Coho and pink salmon were enumerated through electronic counts and area-under-the-curve estimates, while steelhead trout were estimated from electronic estimates and mark-recapture census methods (Ward and McCubbing 1998).

Methods

The Logie 2100C fish counter uses the changes of electrical resistance between electrodes pairs caused by fish passage to provide counts. The date, time, conductivity, channel, direction of movement (up or down) and peak signal size, together with samples of coded values of electrical resistance (trace data) are recorded by the counter when a change in electrical resistance above threshold setting is encountered. When a change of resistance occurs which is not interpreted as a fish count by the counter's fish algorithm, the direction of count is substituted with the character 'E' which denotes an unclassified event. Such events may be fish which have been miss-classified or debris, turbulence and air entrainment noise. These data were downloaded on a daily basis to a portable computer. The counter assigns a signal size to each fish count and event. This signal size is a function of the fish size, counter gain setting (electrode sensitivity), river conductivity conditions and of the channel bulk resistance (a measure of the instantaneous background resistance created by water flowing over the electrodes). A minimum trigger threshold value was set to a peak signal size of 20, on a scale of 1-127, for both upstream and downstream counts and events. Lower threshold levels whilst allowing for the potential enumeration of smaller fish also tend to pick up resistance noise created by water turbulence and entrained air bubbles so are best avoided. A detection limit of 0.5 seconds between fish counts on one channel was selected (the counter can enumerate fish passing over all channels simultaneously). The counter is designed to re-calibrate every 30 minutes for changes in bulk resistance and conductivity (when a conductivity card and probe are present). These calibrations alter the gain setting so that a fish of a standard size will be attributed a similar PSS, under a wide range of environmental conditions. However as no conductivity calibration was available at this site during the video validation period (added in November 1998), two manual gain settings were utilized during the study period. The first setting, a fixed gain of 100 was used to identify a range of species and age classes through jack coho, pink and adult coho salmon, under low flow conditions (August 15th to October 5th), whilst the second setting of 200 was used to determine the range of signal sizes associated with pink and coho salmon under medium and high flow conditions (October 6th to November 1st). A small variance in sizing on a day to day basis may be expected when automated gain settings are unavailable.

These data obtained from the fish counter were analysed in relation to video footage recorded using a video camera (Sony, Hi8, model nos CCD-TRV99), the methods of set up as described in Aprahamian et al (1995). Similar studies in the United Kingdom (Fewings 1987; Welton et al. 1987; Dunkley 1991) have demonstrated the utility of this video validation methodology. Counter efficiencies were based on the number of fish viewed passing over the counter in relationship to the number correctly assigned as upstream or downstream counts by the electronic counter. Other resistivity changes due to fish migration (but not correctly counted) were assigned a variety of event classes for analysis. These included single upstream migrating fish incorrectly logged as an event (UE), two upstream fish migrating simultaneously, logged as one event (UDE), two upstream migrating fish counted as one upstream fish (UDC), multiple upstream migrating fish logged as an event (UME), and single, double or multiple upstream migrating fish with no record (UM).

Area-under-the-curve estimates of pink and coho salmon were undertaken using the stratified index sampling design, this method of assessment has been shown to be produce less biased estimates than

stratified random sampling (Irvine et al. 1992). Twelve 200 to 250-m sites were selected for coho enumeration, based on habitat characteristics, historical knowledge of spawning areas, (Johnston et al 1987) accessibility, and location within the watershed, (Table 1, Fig. 3). A further set of eight partially overlapping sites was used for pink salmon, (Table 2, Fig. 3). Visual surveys were conducted at each site twice each week during the spawning season (August to November) when water conditions allowed. Escapement estimates for pink and coho salmon were calculated by plotting fish population estimates (corrected for observer efficiency) against time, and dividing the area-under-the-curve by the residence time determined by mark-recapture. Data were analyzed using a software package designed for this purpose (Irvine et al. 1993).

Daily survey counts were made by two observers walking upstream through each site recording total adult and jack numbers; fish hiding under cover being displaced with long poles. A value of observer efficiency *oe* for all fish (required in the AUC program) was calculated for each species (excluding coho jacks where few fish were observed and a value from Black Creek was substituted) based on multiple consecutive counts. Several pairs of observers independently counted one site and compared data subsequently. In five cases under variable flow and water clarity conditions the mean of all paired observer counts at a site was compared to the highest paired observer count for that site (assessed to represent a true reach value for that count, although this may represent an over or underestimate in itself). These data were used in calculating *oe*, using the observer efficiency program. Electroshocking as a method of estimating total count to determine observer efficiency was considered but not undertaken due to concerns on the effects on ripe fish and redds already containing eggs found throughout many reaches.

The average time that fish spent in the stream and were visible to observers (residence time) was estimated from the duration of observations of tagged fish in the counting reaches using the restime program which forms part of the analysis software (fish were marked in the lower river at the counting fence and by seining in lower river pools). Residence time and observer efficiency were estimated separately for each species.

Table 1. Stratified Sampling Site Data – Coho Salmon (length in meters).

Strata	Site name	Stratum length (m)	Site length (m)
1	West Tributary.	9000	250
1	Cutthroat Creek	3500	250
2	Misty Lake Outflow	5300	250
2	Misty 1500 Tributary	4000	200
3	O'Conner Tributary	6000	250
3	Tributary downstream of Cub Creek	4000	200
4	West 80 (main stem)	2500	250
4	West Main (main stem)	2500	250
5	Wolfe Creek (main stem)	4000	250
5	Downstream of Keogh Lake (main stem)	1500	200
6	Wolfe creek	1500	250
6	Upstream of Keogh Lake	2000	250

Table 2 Stratified Sampling Site Data – Pink Salmon (lengths in meters).

Strata	Site name	Stratum length (m)	Site length (m)
A	Fish Fence	1250	250
A	Pumphouse	1250	250
B	Sandstone	3500	250
B	W400	3500	250
C	Rupert Main	4000	250
C	Misty 1500	4000	250
D	West 80	2500	250
D	West Main	2500	250

Mark-recapture estimates of steelhead trout were calculated from rod census data and kelt recaptures at the Keogh smolt fence (Ward and McCubbing 1999). The Peterson mark recapture equation was used for comparative population estimates for steelhead trout;

1 $N = (M+1)(C+1)/(R+1)$

where

N = Petersen population of estimate

M = number marked adults

C = number of captured kelts

R = number of recaptured kelts/adults

Species Identification and Peak Signal Size.

Fork lengths and fish mass data were collected from trapped, rod caught and seined. Estimates were also taken from video observations. In all cases, date of measurement, species and method of capture was recorded. The fish counter produces a peak signal size (PSS) for any up or down count. This relative measure of fish size relates to a fish's mass, as indicated by the volume of water it displaced when passing over the counter. Larger fish produce a larger change in resistance and thus a larger Peak Signal Size. A relationship between PSS and fish weight can then be determined for fish swimming at a fixed height above the electrode array. This in turn can be expressed as a fish length if a weight/length relationship is available.

RESULTS

Counter Efficiency

Counter efficiencies varied over the study period with a range of 46% to 100% dependant on environmental conditions, number of fish passing the counter per unit time and tidal cycle. Over 40 hours of video footage stratified across the six months of counter operation, were examined when no fish were viewed traversing the counter. During these periods, no "UP" or "DOWN" counts were recorded. This indicates the stability of the equipment through a range of flow and conductivity conditions and periods of zero count can therefore be assessed to be very accurate.

We recorded and analysed over 50 hours of video footage under suitable light and turbidity conditions when fish were migrating (including night filming with infra-red illumination). Results were recorded as numbers of fish counted by the fish counter (above threshold value, up counts) compared to observed fish on the videotape. Efficiencies of the counter calculated from these data, other than for periods of tidal influence ranged from 70 to 100% with mean efficiencies by species in the range of 88-94% (Table 3). Standard deviations on count efficiencies ranged from 9 to 12%. The mean of all video validation efficiencies regardless of species was 93%, excluding salt water intrusion periods.

Two tide events coincident with low river flow conditions, caused saline water to back-up over the counter channels resulting in poor counter efficiency. These events were predicted from tide tables (and observed low flows). Fish passing through the counter were enumerated by observers stationed at each channel during the period of tidal influence as were fish by-passing the counting channels. Video validation during these two periods recorded fish passing over one channel with a count efficiency of 61% and 46%.

Table 3. Range of counter efficiencies during video validation on the Keogh River 1998. (nf = no fish observed)

	No. of fish observed on video	No. of fish electronically counted	% Counter Species Efficiency			
Date			All	Coho	Pink	Jack Coho
17-Sep	4	4	100	nf	100	nf
19-Sep	46	45	98	100	100	93
21-Sep	20	20	100	nf	100	100
20-Sep	1	1	100	nf	100	nf
22-Sep	18	18	100	nf	100	100
24-Sep	161	145	90	nf	90	nf
27-Sep	18	18	100	nf	100	nf
05-Oct	305	247	81	80	82	nf
07-Oct	62	51	83	88	70	75
07-Oct	109	90	83	82	100	nf
09-Oct	6	6	100	100	nf	nf
Totals	744	640				
Average			94	88	94	92
S.D.			8	9	10	12

There were several reasons for fish passing over the counter without being correctly counted. The majority of the error in counting was attributed to single fish passing over the counter in a manner that they were logged as an event rather than an upstream count. Missed fish with no record were extremely rare and always close to theoretical threshold size (based on PSS to fish length relationship), while multiple fish passing through the counting channels and being recorded as an event resulted in most of the remaining counting error (Table 4).

Table 4. Reasons for inaccurate counts, Keogh River 1998.

Error reason	Code	Number of observations	Percentage of total error
Upstream correct	U	509	-
Upstream event fish	UE	35	7
Upstream missed	UM	3	0.5
Upstream double count	UDC	4	0.5
Upstream double event	UDE	12	2

Fish sizing

During low flows (which dominated the summer and early autumn of 1998), the counter was set up to estimate the numbers of all sizes of salmonids species observed migrating. A sample of pink salmon and coho salmon adults was seined from a side channel adjacent to the counter site. The length frequency of these data shows only a small overlap of in the 55-65cm length class of the two species (Fig. 4). From video data collected during these periods of low flow (<10cm water depth over any counter weir crest), a similar pattern of only a few coho adults and pink salmon were observed for the peak signal size class in the range of 120-126 (Fig. 5). Jack coho sampled were in general smaller than all pink salmon sampled, in both length and weight, although only low numbers of jacks were sampled. They also produced smaller PSS estimates, than pink salmon.

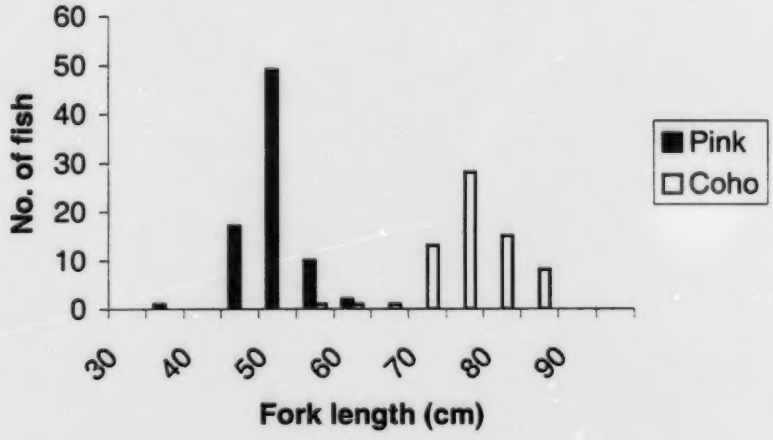

Figure 4. Length frequency distribution of a sub-sample of pink and coho salmon from the Keogh River in September of 1998.

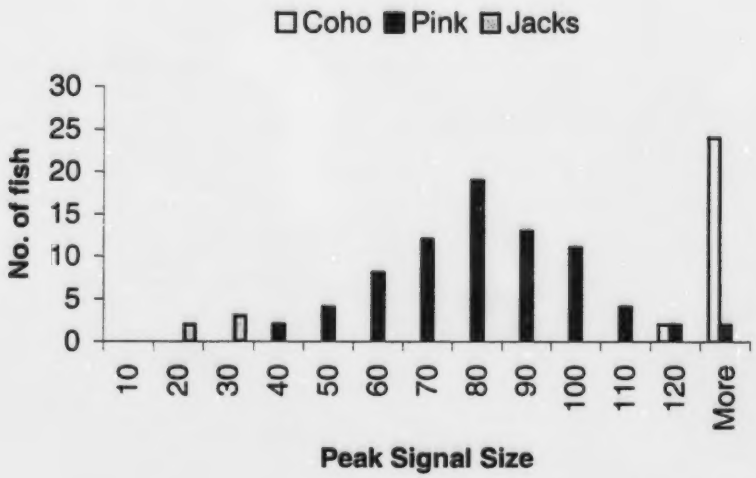

Figure 5. Peak signal size (PSS) of salmonids observed from video, Keogh River 1998.

Using these data it was possible to partition the pink salmon and coho salmon counter estimates during low flow conditions:

Jack coho salmon	PSS < 40
Pink salmon	PSS > 40 <126
Coho adults	PSS < 126

Using these criteria, 2.6% of pink salmon "up count" records were falsely classified as coho adults, based on comparison to actual data from video, while 7.7% of coho adults were falsely classified as pink salmon. As the data which were examined during this period of low flow migration indicated pink salmon were three times more abundant then coho salmon, this error when compounded resulted in very little miss-classification of counts based on PSS alone.

To summarise, using an example based on the data in Figure 4; 26 coho salmon were assessed to have been counted (using fixed signal size criteria) with a video observed count of 24 coho adults. The error of 2 fish classed as coho salmon which were actually pink salmon is cancelled out as during this same time period 77 pink salmon were counted with a video observed error of classification also of 2 fish, which were actually coho salmon. The net identification error resulting from the use of this fixed method was zero.

During these low flow periods, a strong relationship (Fig. 6.) was observed between transformed video fish length data and PSS, with much of the variation in observed fish length explained by PSS (equation 2, $r^2 = 0.85$, n = 81, maximum signal sizes excluded).

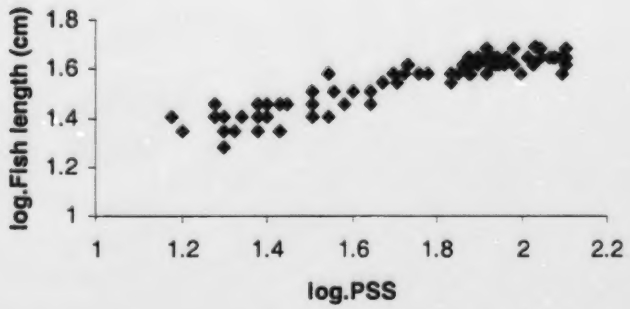

Figure 6. Relationship of log.observed video length (cm) to log.PSS in salmon passing over the Keogh counter in 1998.

From this relationship equation 2, can be used with some precision to estimate the length frequency of pink salmon migration without the need to handle fish, (Fig. 7.)

2 $$\log_{10} PSS = 0.328 \bullet \log_{10}(L) + 0.977$$

where L = fish total length in cm (from video observations)

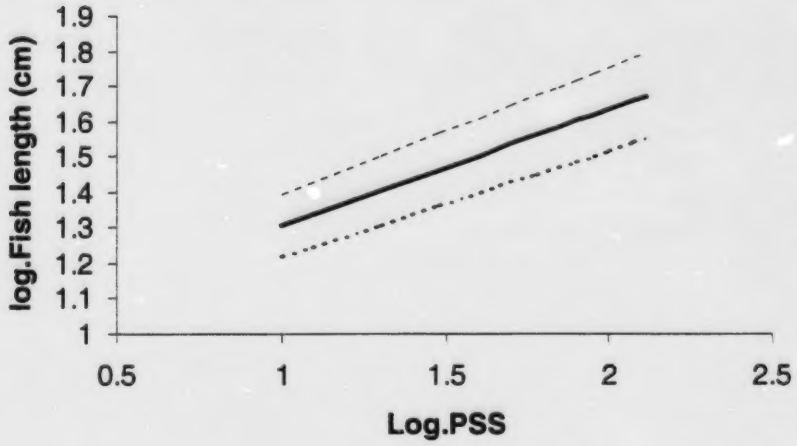

Figure 7. Log.PSS to log.fish length (in cm) relationship with 95% confidence limits, based on salmon video observations on 24th September 1998, Keogh River (from equation 2).

An increase in river discharge occurred on the 6th of October following a heavy rainfall. The counter set up was altered to focus enumeration and sizing on pink salmon and coho adults only as few jack coho were observed migrating. The counter gain was reduced to 100, to allow sizing of coho salmon adults and larger pink salmon (greater than 35cm length required to exceed counter PSS threshold value of 20). The results observed from analysis of video footage on the 7th-9th October, show a range of fish lengths associated with similar peak signal sizes. In general smaller pink salmon could not generate large peak signal sizes, but significant numbers of larger coho did generate small peak signal sizes, (Fig. 8).

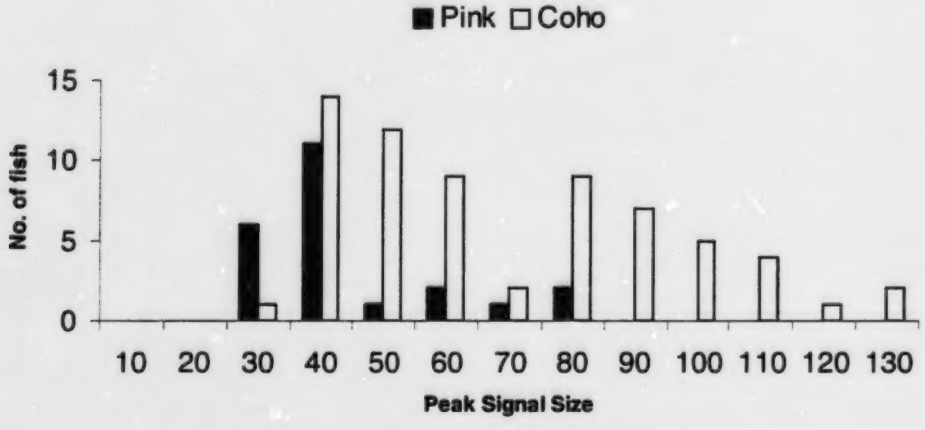

Figure 8. Fish length from video validation versus peak signal size (high flow conditions >10cm flow over weir crests).

On site visual observations and videotape footage indicated low numbers of pink salmon (less than 5% of all salmon counted in this period) migrated during this increase in river discharge. No significant relationship between PSS and fish length could be observed from video analysis on Channel 1 at these flows. Thus fish escapement estimates at this time could only be calculated by multiplying the count by the ratio of pink/coho salmon as seen from video footage, ignoring peak signal size. Observations of PSS variance during high flows indicated that differential sizing was occurring between channels, possibly associated with swimming height of fish above the electrodes. Fish passing over the electrodes of channel 3, with a downstream gradient 1:6, produced a larger PSS (mean 82, compared to 74 on channels 1&4 combined, ANOVA, $p<0.05$, $n=418$). Channels 1 and 4 had downstream weir gradients of 1:10 and 1:8 respectively.

Enumeration Estimates

Counter

A variety of enumeration estimates can be determined from the fish counter raw data, fish sizing information and observed counter efficiency, as recorded by the video validation study. Methods of escapement estimation include; taking a mean counter efficiency of all validation observations for all species and raising the counter raw data to accommodate for this efficiency. For example a total of 7500 coho salmon were counted by the fish counter, based on a PSS of >126 at low flows and 95% species composition (from video) at high flows. Using the fish counted to fish observed ratio of all species of

fish, from all video validation observations except tidal influenced periods, 86% of the fish which passed over the counter were enumerated. Thus a total escapement of 8720 coho salmon can be derived from the equation 3.

3 $$E = c/e * 100$$

where E = escapement, c = total counter up count, and e = mean efficiency of all observations.

However this estimate may be biased for several reasons; the counter may exhibit different efficiencies for different species, the counter efficiency may vary with flow conditions, and/or the counter efficiency may vary with number of fish passing in any given period of time, t.

From video analysis, counter efficiency was observed to alter with species, although variance was generally lower (average S.D. = 2%, range 0-10%) than between sample days (average S.D. = 10%, range 9-12%). The greater part of variation in counter efficiency could be accounted for by flow conditions and the number of fish migrating in a unit of time. Efficiencies at low flows, defined as less than 10cm depth over the weir crests, showed a strong negative logged relationship ($r^2 = 0.97$, n=8) when compared to increasing numbers of fish passing in any set time period (per hour being used here for comparison). The number of data points are however limited (Fig. 9).

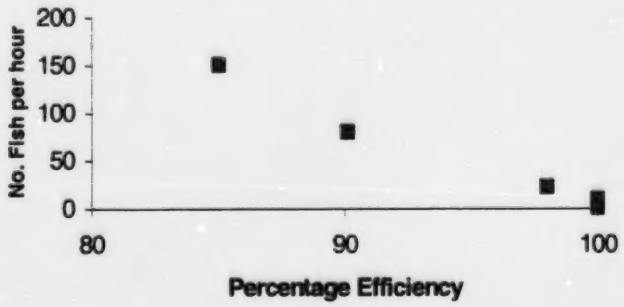

Figure 9. The logged relationship between counter efficiency and number of fish migrating per hour.

Because of variations in count efficiency, a better escapement estimate may be derived from taking the daily count efficiency as assessed from video footage and entering this into equation 4.

4 $$E = c_t/e_t * 100 + c_{t+1}/e_{t+1} * 100 + \ldots \quad \text{through time } T$$

where c_t is the electronic count on day one, c_{t+1} is the electronic count on day two, through the time series, t = 1 to t= T (T being the total number of days in the study) and e_t is the efficiency from video validation on day one and e_{t+1} is the counter efficiencies on each subsequent day except when no daily efficiency

value was available. In this case the efficiency of the nearest date on which similar flow and fish migration numbers occurred was substituted. Species identification for enumeration purposes was based on PSS at low flows and video observations at high flows. Using equation 4 a coho escapement estimate of 8246 adults was derived, for the study period of September 3rd to November 22nd 1998 whilst pink salmon escapement was estimated at 8508 adults in the period August 1st to November 1st.

To estimate steelhead escapement two values for counter efficiency were applied to equation 3. An uncorrected total of 74 upstream migrating steelhead were counted passing the weirs on the Keogh in 1999. Equation 3 thus provides a population estimate of steelhead escapement of 82 steelhead entering the Keogh river from the 1st of December 1998 to April 6th 1999, based on a 90% count efficiency (the average of all video validation), or 92 adults if the lower efficiency of 80% is applied (the average efficiency of count for coho under more typical high winter flows). Jack steelhead (less than 500mm in length) were not counted under winter gain settings, as the threshold length was 550mm.

AUC

Area-under-the curve estimates for coho salmon were undertaken from the data collected on 12 sites through the spawning period of 20th October to December 17th 1998. The computer program compensates for missing data (Irvine et al 1993). A total of 516 pink salmon and 87 coho adults were tagged at the fish fence and within river. Results of observations of tagged fish are shown in Appendix 1a and 1b.

No tagged coho were observed and only low numbers of tagged pink salmon were observed. Residence times for coho AUC estimates were taken from Irvine et al 1992, Simpson (pers.comm) and English et al 1992. These ranged from 5 days to 12 days. For pink salmon a value of 2.29 days was used based on visual observations of the few tagged fish observed within two of the sample reaches and using the *restime* program associated with the AUC calculations (Irvine et al 1993). Observer efficiency (*oe*) of tagged fish could not be established due to the lack of tags.

Observer efficiency *oe* values for all counts were assessed using the computer program to be in the range found in other studies, but caution must be used in accepting these values. Varied flow conditions and coloration through cedar staining made some sites very hard to assess on some occasions. A more detailed study of observer efficiency may reduce or increase the value applied, resulting in changes in the overall AUC estimate.

Using the observed and calculated values, the AUC program (Irvine et al 1993) estimates a pink salmon escapement of 15,631 fish, whilst coho estimates were varied (range of 5411 to 13060) and dependent on which value was used for residence time from the literature, (Table 5).

Table 5. Area-under-the-curve estimates of coho abundance, Keogh River 1998.

Life Stage	Residence Time (in days)	Population estimate
Adult	5	13,060
Adult	8.5	7,682
Adult	12	5,411
Jack	5	197
Jack	8.5	116
Jack	12	82

Mark-recapture

Steelhead enumeration was possible using the fish counter and by mark-recapture methods (see Ward and McCubbing 1998). A total of 53 steelhead caught angling were tagged with a gill plate punch during the migration period of December 1998 to April 1999. This represents 57% of the maximum count estimate. A total of 39 were wild origin (73% of sample) and 14 were adipose clipped hatchery strays (27% of sample).

During subsequent fence operations after the 7th of April and until fence removal on June 18th, 49 kelts were recovered by seining and trapping. Of these fish, 22 showed evidence of punch holes, consisting of two hatchery strays and 20 which were wild fish.

In addition, a number of down counts were recorded by the fish counter prior to full fence placement, suggesting some early kelt/fish out migration. This was confirmed by the capture of two gill plate punched fish in the nearby Cluxewe River during broodstock collection.

Three mark recapture estimates are possible based on the data obtained, total escapement, wild escapement and hatchery escapement (Table 6). All jack steelhead under 550mm in length were removed from these calculations as they are below the detection limit of the counter during winter settings.

Table 6. Steelhead Mark recapture estimates for the Keogh River 1999.

	No. marked	No. sampled	No. recaptures	Population Estimate	95% Confidence limits (+/-)
All steelhead	49	48	24	98	67 - 149
Wild steelhead	37	48	22	81	54 - 126
Hatchery strays	9	3	2	13	5 - 33

Migration Timing

Detailed analysis of daily migration patterns were undertaken, for coho and pink salmon. Plots of daily fish passage of both species is shown in Figure 10 (note log scale). Pink migration in August and early September co-incided with small rainfall and flood events (data on file), whilst in late September and early October migration was steady and appeared unrelated to river level. Peak coho salmon migration peaked after rainfall events particularly the flood of October 6th to 9th, when 73% of the total escapement occurred, although high tide events also resulted in smaller migration peaks.

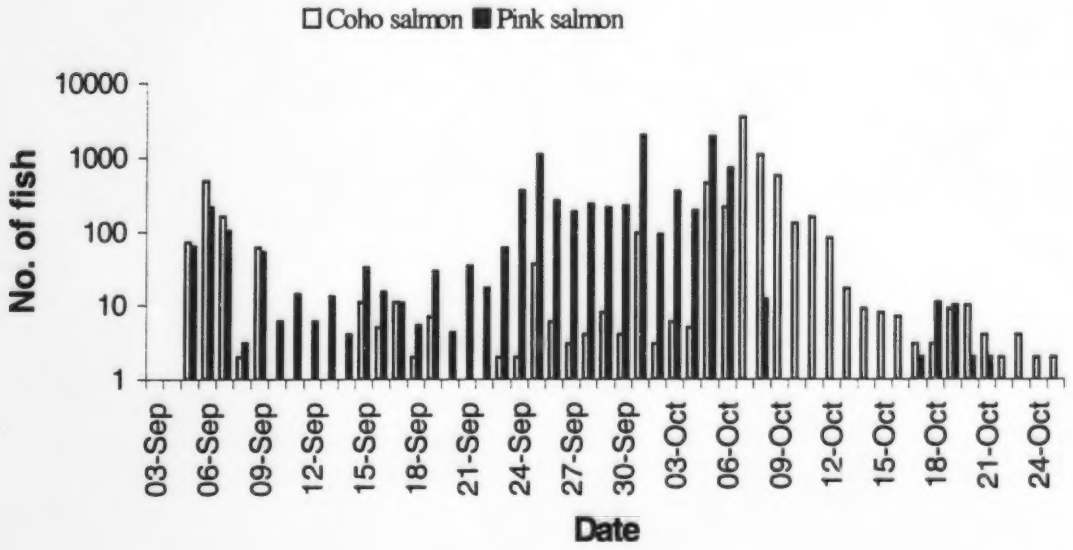

Figure 10. Coho and pink salmon, daily numbers electronically counted in the Keogh River in 1998, corrected for count efficiency.

DISCUSSION

Counter operation

The Logie 2100C fish counter was found to be a reliable method of estimating escapement of coho and pink salmon and with logging of trace data, a reliable monitoring method to estimate steelhead escapement. Some problems were experienced with the counters operation at this site in 1999, relating largely to power supply interruptions and salt water intrusion under extreme spring tide events. The power supply problems stemmed from the reliance on solar and wind methods used for battery charging and will be eliminated through an extension of the solar element of the charging unit. Salt water intrusion cannot be eliminated as it is due to the site's location on the existing fish fence sill. Whilst relocation of the counter upstream would resolve this problem, associated costs would be high. Instead, re-design of the diversion fence (to avoid fish passing over during periods of the highest tides), the introduction of a multiple weir channels (wide channel design), and replacement of the sill boards to increase water flow over (rather than through) the structure, will resolve all but a few high tide events which can be predicted and manually observed for fish counter efficiency.

Counter Efficiency

Video validation was carried out under a variety of conditions through the migration period of pink and coho salmon. No validation was undertaken on steelhead due to the very low escapement and the many hours of recording/analysis which would have been required for any significant quantity of data. Rather, efficiencies for similar conditions of flow during coho migration were applied to steelhead data. Future work could incorporate a counter event-triggered still photograph which would provide an optional validation method, although sizing estimates may still be problematic (Nicholson et al 1996). Data collected for pink salmon migration were largely related to low flow conditions as drought conditions persisted for much of July, August and early September. Visual observations of thousands of pink salmon repeatedly entering the river on high tide events during these months but choosing not to commit to moving into freshwater, indicated water flows were unsuitable for migration. Thus, peak migration occurred in small bursts during or immediately preceding small rainfall events, as seen on other river systems (McCubbing pers.obs.). Counter efficiencies for pink salmon ranged from 70% to 100% (mean 94%), whilst counter efficiencies for coho salmon varied from 80-100% (mean 88%). These are typical of Logie counter efficiencies observed in other studies on trout and salmon migration (Aprahamian et al 1996, Nicholson et al 1993, Fewings 1991). A strong negative non-linear relationship was found between the number of fish migrating per hour and counter efficiency. This was partly explained from video as being a result of multiple fish traversing one channel simultaneously and being counted either as one large fish or an "event". Species composition , river level and channel selection may explain much of the remaining variance, but data are limited due to the few days on which significant numbers of fish were observed migrating.

During the analysis of video footage, only one fish (above threshold size), in 744 observations, was identified from video has having fully traversed the electrode without an associated counter record. This fish was small and may have passed high in the water column resulting in a signal below threshold settings. Thus almost all fish and fish created events would have produced a descriptive trace for later analysis had this been collected throughout the migration period. Post analysis of trace data can an effective method for assessing/confirming escapement efficiency corrections, based on blind tests of observer analysis compared to recorded video footage (McCubbing 1999 pers.obs).

Fish Sizing

Fish sizing estimates were found to be sufficiently accurate at low and medium flows to distinguish pink salmon from coho salmon and coho jacks with a high degree of accuracy. This was in part due to only partial overlap between species based on actual fish length or weight and in part due to good sizing data from the counter. Miss-classification of species was in the range of only a few percentage points. Thus the error associated with using PSS to determine species identification under low flow conditions in providing escapement estimates is very limited.

However under high flows only a weak relationship was identified for coho salmon length and counter peak signal size (few pink salmon were observed on video migrating under these higher flows). As the counter is designed to more accurately determine the weight of a fish (a closer approximation to water displacement or volume, the measure of electrical resistance to which PSS relates) it was considered that high variance in PSS to video length may have been a function of natural weight/length variance in coho adults. However, analysis of a limited sample of weight/length data for adult coho resulted in a high level of weight variance being explained for by fish length ($r^2 = 0.95$, n = 41, data on file). Thus it seems more likely, based on observations in 1997 during site testing (McCubbing and Ward 1998) that the variance observed was a result of fish swimming height. This was also observed in work on the River Lune, England, (Nicholson et al 1995), where video length was shown to vary with swimming height, as does peak signal size at low conductivity. To determine which creates the greater error, side view video footage would be required. Proposed alterations in downstream weir slopes to gradients of 1:5, which will decrease water velocity close to the weir surface (Crump 1954) should encourage fish passage close to the electrodes even under elevated flows. This will improve sizing capabilities in future operations. Such alterations should not create velocities which preclude the migration of coho jacks or pink salmon based on observations of fish passage versus channel water velocity in 1998.

Escapement Estimates

The Logie 2100C fish counter gave efficiency corrected escapement estimates of 8246 coho adults, 8508 pink adults (from August 15th) and between 82 and 92 steelhead adults.

Pink adults were separately enumerated by AUC methods with river specific residence time values. This estimate of over 15,000 pink salmon is likely a significant over estimate of escapement even allowing for the small migration of pink adults which was observed prior to counter operation. The calculated residence time of 2.9 days is based on very few re-sightings of tagged fish and no confidence limits are available on the estimate. In addition a large flood on the 7th of October two days after peak migration resulted in the loss of critical data on the peak spawning period, with many redds observed in areas where no pink salmon had been counted prior to or after the event. The potential for accurate assessment of pink adults through this method is low without increased effort and perhaps a change to mark-recapture/dead pitch methods (see Johnston et al 1986) which would require significant handling of a much reduced escapement. Resources were high for this method of analysis with over 25 person day equivalents required for field stream counts. Given an estimated cost of $200 per person day this survey would cost $5000 per year to undertake.

Coho adult escapement was also estimated through AUC methods. However insufficient adults were tagged and re-sighted (despite considerable effort on tagging) for a local value of residence time to be calculated. Several estimates were used from the range available in the literature (Irvine et al 1993, English 1992), but the problems involved in this method are apparent in the resulting escapement estimate. Using a typical residence value of 12 days as seen in other small and moderate sized coastal streams (Simpson pers.comm.), would have under-estimated the escapement by at least 40%. The reasons

for this are complex but may include poor estimates of observer efficiency due to variations in water clarity, flow, and observer diligence. Seasonal variations in residence time (with run component), spatial distribution of fish through the watershed through time and varied residence time in tributaries and main stem spawning areas all affect the result (see Irvine et al 1992). A total of 76 person days were spent collecting these data and this effort would likely be increased substantially if the questions on the values of residence time and observer efficiency were to be sufficiently addressed to give and acceptable level of confidence to the data acquired. Thus typical yearly costs of collecting this data would be in excess of $15,000, without increased effort to provide residence data, which was estimated to take at least a further 22 days (or $4400) on Black creek (Irvine et la 1992) which is smaller and therefor easier to assess.

Steelhead enumeration was undertaken in comparison by mark recapture techniques, as in 1997. Counter estimates of all steelhead escapement ranged from 82 to 92 fish. Data initially suggests the counter under-estimated steelhead escapement estimates (even with an 80% efficiency of count correction factor, giving higher escapement value). The mark recapture population estimate on all steelhead was 98 adults, although confidence limits range of 67 to 149 fish. However in this calculation hatchery strays represent a much smaller proportion of recaptured fish than in the tagging sample. This will tend to bias the overall population estimate high for all fish combined. Reasons for this observation are unclear but may relate to early kelt migration in hatchery strays prior to fence installation. Thus analysis of the wild fish component was undertaken separately. In this case wild fish represent 81 of the total 98 fish mark-recapture estimate. Counter estimates of wild/hatchery stray components can only be based on the proportion of each group marked in the tagging study. In this way, based on a monthly sample ratio of wild to hatchery strays, a total of 76 wild steelhead were counted (80% count efficiency correction factor). This counter estimate is close to the mark-recapture estimate and is well within the upper and lower confidence limits associated with the mark-recapture experiment (54 to 126 fish). It would thus be a reliable estimate of steelhead escapement in the absence of alternate enumeration data.

Migration Timing

Migration timing of pink salmon was consistent with that observed in previous studies (Johnston et al 1986). Fish entered the river on greatest numbers in late September and early October and spawned by late October. Coho salmon migration was also similar to results published by Johnston (et al 1986), although a tri-modal pattern was observed. Peak migration coincided with the same early October period in both studies.

Project Costs

Current site development in capital costs was around $45k, although use of the existing sill and only development of partial coverage kept this value low. Typically a purpose built site may be developed with a permanent structure from $100k for a small river (10-12 meters bank-full width) to several hundred thousand for larger systems where suitable sites exist (i.e. Deadman River, Thompson Basin, BC). Yearly operating costs on the Keogh River for electronic enumeration of pink and coho salmon and steelhead trout will be around $15k, although a further $40k will be required to completely cover the sill with counting channels, thus eliminating the diversion weir and the possibility of some fish by-passing the counter under high flow events. This figure may be higher than other sites due to the dual application of the sill as a juvenile and adult monitoring site. On purpose built sites operating costs may be reduced to a few thousand dollars, depending on run size and timing.

Typical fence operating costs should full river trapping be attempted would exceed $35k annually (for all species) with the potential for years where fence flood damage would result in significantly higher maintenance costs. Due to the high autumn discharge in such coastal streams, fence operation would be

difficult in many years and may not provide escapement estimates in all years, requiring additional mark recapture estimates as seen at other sites in B.C. Area-under-the-curve estimates in 1998 required an investment of around $32k in total for pink and coho salmon estimates, whilst steelhead mark recapture data collection required a budget of $11k, but also provided much needed biological data to determine age class structure of returnees.

CONCLUSIONS

The value of accurate and precise escapement estimates is well understood in escapement based fisheries management. The Pacific Fisheries Resource Conservation Councils in it's first annual report highlights the need for improved and more accurate enumeration of salmon escapement to improve management, and specifically notes the potential of electronic enumeration techniques (Anon 1999). In addition recent evidence of poor ocean survival in steelhead trout and many salmon species (Ward 1999 and Welch pers.comm.) requires better monitoring methods if escapement estimates are to be accurate and the effects of climate change are to be fully understood.

Coho smolt enumeration historically and currently undertaken at the Keogh fence will allow for marine survival estimates by brood year in future studies, similar to studies currently undertaken on steelhead at this site. Coded wire tagging of wild smolts will be an essential part of this ongoing study to address in-season coho smolt migration values, adult straying and catch estimates (Simpson pers.comm.).

The fish counter operation on the Keogh River in 1998 provided acceptable escapement estimate of coho and pink salmon and steelhead trout adults. Video validation indicated the stability of the counter and the ability through counter sizing and visual observations of species composition at one site to determine escapement of salmonids without the requirement for the handling of fish. It also indicated the need for slight modifications of weir slope to improve sizing estimates at higher river flows. Further improvements to data collection is proposed for 1999.

Comparative methods of escapement estimate generation, either gave similar results (steelhead) or had questionable reliability and/or significant costs associated with data collection and analysis (coho and pink salmon). Significantly increased effort on tagging of coho adults and therefor handling would be required for improving the accuracy of AUC estimates on this coastal system. Alternative methods of enumeration, (e.g. a traditional fish fence) at this site would not have been able to withstand the flood associated with peak coho migration and assuming such a structure had remained operational, the logistics of processing over 4,000 fish in a 24 hour period would have resulted in delaying migration of ripe fish in a year of exceptionally low flows. The effects of such a delay in migration would be impossible to establish. In contrast high flows in January and February during the steelhead migration would have resulted in damage to the fence had it been used for late run steelhead migration.

In summary this project has demonstrated the usefulness and economic advantages of a resistivity fish counter on a coastal B.C stream which is unsuited to alternate methods of salmon escapement. The application of counter technology at this and other sites should form a useful data for the future and sustainable management of pacific salmonids on the West coast.

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Appendix 1a: Coho AUC Counts Keogh, 1999

	20-Oct		30-Oct		02-Nov		05-Nov		09-Nov		17-Nov		20-Nov		24-Nov		30-Nov	
	Adult	Jack	Adult	Jacks	Adults	Jacks	Adults	Jacks	Adults	Jacks	Adults	Jacks	Adults	Jacks	Adults	Jacks	Adults	Jacks
Upper Keogh	1	0	17	1	22	0	19	1	7	1	44	1	27	1	25	0	4	0
DS Keogh Lake	1	0	9	4	30	0	21	0	19	0	8	1	43	1	1	0	14	5
Wolfe Creek	0	0	0	0	0	0	0	0	13	3	7	0	10	0	5	1	3	0
Wolfe Creek (Main)	29	0	66	1	29	0	28	1	0	0	n/c	0	18	0	nc	nc	6	0
O'Conner	0	2	2	0	2	0	0	0	1	0	2	0	2	0	nc	nc	10	0
West Main	3	0	4	0	2	0	6	0	0	0	n/c	0	nc	nc	nc	nc	nc	nc
West 80	3	0	2	0	6	0	0	0	1	1	n/c	n/c	nc	nc	nc	nc	nc	nc
Cub Creek	0	0	0	0	nc low	nc	nc	nc	0	0	0	1	1	1	1	1	0	0
Misty 1500	0	0	0	0	nc low	nc	nc	nc	0	0	6	0	nc	nc	3	0	1	0
Misty Lake (inflow)	1	0	0	0	0	0	0	0	0	0	0	0	nc	nc	11	0	0	0
Cutthroat	0	0	2	2	2	0	2	0	0	0	3	0	0	0	13	0	1	0
West Trib	26	0	32	0	27	0	24	0	nc	nc	n/c	n/c	4	0	25	0	12	0

Appendix 1b: Pink Salmon AUC Counts Keogh, 1998.

Pink Live

Site	Date 17-Sep	20-Sep	24-Sep	28-Sep	01-Oct	05-Oct	21-Oct	27-Oct
Fence	0	6	59	120	220	205	nc	nc
Pump	0	2	4	48	85	184	13	nc
Sand	0	0	0	6	4	5	0	nc
Beer Bottle	0	0	0	0	0	0	1	nc
Rupert Mn	0	0	0	0	0	0	0	nc
Misty	0	0	0	0	0	0	0	nc
West 80	0	0	0	0	0	0	0	nc
West main	0	0	0	0	0	0	0	nc

Pink Morts

Site	Date 17-Sep	20-Sep	24-Sep	28-Sep	01-Oct	05-Oct	21-Oct	27-Oct
Fence	0	1	4	4	6	38	nc	0
Pump	1	0	0	2	6	17	4*	0
Sand	0	0	0	0	1	1	0	0
Beer Bottle	0	0	0	0	0	0	2	0
Rupert Mn	0	0	0	0	0	0	0	0
Misty	0	0	0	0	0	0	0	0
West 80	0	0	0	0	0	0	0	0
West main	0	0	0	0	0	0	0	0

Pink tagged (Live)

Site	Date 17-Sep	20-Sep	24-Sep	28-Sep	01-Oct	05-Oct	21-Oct	27-Oct
Fence	0	2	4	0	1	1	0	0
Pump	0	0	0	0	0	4	0	0
Sand	0	0	0	0	0	0	0	0
Beer Bottle	0	0	0	0	0	0	0	0
Rupert Mn	0	0	0	0	0	0	0	0
Misty	0	0	0	0	0	0	0	0
West 80	0	0	0	0	0	0	0	0
West main	0	0	0	0	0	0	0	0

Pink tagged (dead)

Site	Date 17-Sep	20-Sep	24-Sep	28-Sep	01-Oct	05-Oct	21-Oct	27-Oct
Fence	0	0	0	0	0	2	0	0
Pump	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0	0
Beer Bottle	0	0	0	0	0	0	0	0
Rupert Mn	0	0	0	0	0	0	0	0
Misty	0	0	0	0	0	0	0	0
West 80	0	0	0	0	0	0	0	0
West main	0	0	0	0	0	0	0	0

Yellow tagged (live)

Site	Date 17-Sep	20-Sep	24-Sep	28-Sep	01-Oct	05-Oct	21-Oct	27-Oct
Fence	0	0	0	0	0	4	0	0
Pump	0	0	0	0	0	8	0	0
Sand	0	0	0	0	0	0	0	0
Beer Bottle	0	0	0	0	0	0	0	0
Rupert Mn	0	0	0	0	0	0	0	0
Misty	0	0	0	0	0	0	0	0
West 80	0	0	0	0	0	0	0	0
West main	0	0	0	0	0	0	0	0

Yellow tagged (dead)

Site	Date 17-Sep	20-Sep	24-Sep	28-Sep	01-Oct	05-Oct	21-Oct	27-Oct
Fence	0	0	0	0	0	0	0	0
Pump	0	0	0	0	0	1	0	0
Sand	0	0	0	0	0	0	0	0
Beer Bottle	0	0	0	0	0	0	0	0
Rupert Mn	0	0	0	0	0	0	0	0
Misty	0	0	0	0	0	0	0	0
West 80	0	0	0	0	0	0	0	0
West main	0	0	0	0	0	0	0	0